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COMPLEMENTS AND SUBSTITUTES**

By Jan Potters, Sigrid Suetens

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Cooperation in experimental games of strategic complements and substitutes

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March 2006

Abstract

Results are reported of a laboratory experiment aimed at examining whether strategic substitutability and strategic complementarity have an impact on the tendency to cooperate in two-player dominance-solvable games with a Pareto-inefficient Nash equilibrium. We find that there is significantly more cooperation when actions exhibit strategic complementarities than in case of strategic substitutes.

Keywords: experiments, cooperation, strategic substitutes and complements, externalities

JEL codes: C7, C9, L1

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1 Introduction

Economic agents are often faced with the dilemma of acting in their own interest or pursuing a more cooperative course of action. Well-known examples of such environments include common-pool resource or rent-seeking environments, price and quantity competition, voluntary contribution mechanisms, arms races, and tariff competition. A challenging task for researchers is to identify conditions under which agents are more cooperative than the Nash equilibrium based on the assumption of narrowly self-interested behavior would predict (see e.g., Dawes and Thaler, 1988; Davis and Holt, 1993; Ledyard, 1995). In this paper we present results from a laboratory experiment designed to examine whether the extent of cooperation in dilemma environments is related to the nature of strategic interaction, that is, strategic complements versus substitutes.

Whether choices of agents i and j are strategic complements or strategic substitutes depends on the effect of agent i 's choice on the marginal payoff of agent j 's choice. The effect is positive in case of strategic complements and negative in case of strategic substitutes (see Fudenberg and Tirole, 1984; Bulow et al., 1985):

$$\frac{\partial^2 \pi_i}{\partial x_i \partial x_j} > 0 (< 0) \text{ in games of strategic complements (substitutes).}$$

The sign of the cross-effect corresponds to the sign of the best response function's slope (at least locally). So, an important implication of strategic substitutability is that a change in one agent's choice gives the other agent an incentive to move in the *opposite* direction. This is, for example, the case in a common-pool resource game, a public good game with a decelerating production function, a quantity-choice game with substitute goods, and a price-setting game with complementary goods. Instead, with strategic complementarity, the incentive for agents is to move in the *same* direction. Examples are a public good game with an accelerating production function, a quantity-choice game with substitute goods, and a price-setting game with complementary goods¹.

We hypothesize that strategic complementarity facilitates cooperation in a dilemma environment compared to strategic substitutability. The reason is that in case of strategic complements even a self-interested agent, acting in accordance with the best response function, will partially follow a cooperative move made by another agent. In case of strategic substitutes,

¹Eaton (2004) provides more examples of dilemma environments that are either characterized by strategic substitutability or strategic complementarity.

a self-interested agent will partially off-set a cooperative move. For example, in case of oligopolistic price competition with substitute goods (strategic complements), if a firm that aims at colluding sets a price above the Nash equilibrium level, then the best response for the competitor is to set a price above the Nash equilibrium level as well. In this scenario, the average price will always be more collusive than the Nash equilibrium price. In case of quantity competition with substitute goods (strategic substitutes), however, if a firm sets a (collusive) quantity below the Nash equilibrium level, then a best-responding firm will set a quantity above the Nash equilibrium level. The average outcome will now, all else equal, deviate to a lesser extent from the Nash prediction than in case of strategic complements. The theoretical work of Haltiwanger and Waldman (1991, 1993) that highlights the importance of the nature of strategic interaction for aggregate outcomes is based on this intuition. They show that non-responding (e.g., altruistic) agents tend to have a disproportionate impact on the aggregate outcome if the environment is characterized by strategic complementarity.

In much the same vein our hypothesis is supported by models that analyze the strategic effect of altruistic preferences in two-player games (see, e.g., Rotemberg, 1994; Bester and Güth, 1998). The main idea is that under strategic substitutability being altruistic is detrimental in material payoff terms, because altruistic acts (such as moving from the Nash equilibrium in the direction of the joint payoff maximum) are never followed by a self-interested agent. In games of strategic complements, however, being at least somewhat altruistic does pay off: it triggers a favorable response by a self-interested agent, and this improves both agents' material payoffs.

The experiment discussed in this paper is designed in order to examine *ceteris paribus* whether the nature of strategic interaction has an impact on the extent of cooperation in two-player dominance-solvable games with a Pareto-dominated Nash equilibrium, which is a well-known class of social dilemma games. It consists of neutrally framed strategic substitutes and complements treatments with the same standard theoretical benchmarks and corresponding payoffs. In order to control for the sign of the externality—the literature on framing effects in public goods experiments suggests that environments with a positive externality are more prone to deviations towards cooperative play than environments with a negative externality²—we included treatments with a positive externality and treatments with a negative externality.

A number of experimental studies is related to ours. In the experimen-

²See Andreoni (1995); Sonnemans et al. (1998); Willinger and Ziegelmeyer (1999); Park (2000) and Zelmer (2003). Brewer and Kramer (1986), however, find a framing effect in the opposite direction of Andreoni's original results.

tal industrial organization literature, for instance, there are indications that in a strategic complements environment play is more cooperative than in a strategic substitutes environment³. However, these experiments do not give conclusive evidence on the effect of the type strategic interaction since the *ceteris paribus* condition is not satisfied. Firstly, actions are differently framed in different treatments (e.g., price versus quantity choices). Secondly, the sign of the externality covaries with the type of strategic interaction. For example, typical Cournot games are characterized by negative externalities *and* strategic substitutes, while Bertrand games have positive externalities *and* strategic complements. Finally, in the experiments the benchmark outcomes and payoffs (Nash, joint profit maximum, optimal defection) vary with the type of strategic interaction. In our experiment, we rule out these potential confounds.

Also related is the experimental study by Fehr and Tyran (2002)⁴. Motivated by Haltiwanger and Waldman (1985, 1989), they examine the adjustment of prices after a macro-economic shock. They find that this adjustment is slower if the game has strategic complementarities compared to a case of strategic substitutability. An important difference with our study is that Fehr and Tyran focus on the speed of convergence and do not address issues of cooperation. This is reflected in their choice to implement games with an *efficient* Nash equilibrium. Fehr and Tyran explicitly mention that they want to rule out “that collusion slows down adjustment towards equilibrium”⁵. Whether collusion (cooperation) occurs more frequently under strategic complementarity than under strategic substitutability is precisely what we are interested in.

The remainder of the paper is organized as follows. In section 2 we explain the experimental design and the procedures. The experimental results are presented in section 3 and section 4 contains concluding remarks.

³See Holt (1995); Huck et al. (2000); Davis (2002) and Suetens and Potters (2005) for Bertrand/Cournot applications and Suetens (2005) for an R&D application.

⁴See Fehr and Tyran (2005) and Camerer and Fehr (2006) for discussions of other related experimental findings.

⁵Chen and Gazzale (2004) is a study that examines the impact of the *degree* of strategic complementarity on the speed of convergence towards equilibrium. In their study the equilibrium is also efficient and hence cooperation is not an issue.

2 The experiment

2.1 Design

Since our aim is to examine whether the nature of strategic interdependence has an influence on cooperation in dilemma games, we design strategic substitutes (SUBST) and strategic complements (COMPL) treatments. In all treatments fixed pairs of subjects play a finite repetition of the same stage game. We implement quadratic payoff functions, and ensure that the stage game is dominance-solvable, has a unique and Pareto-dominated Nash equilibrium, and a symmetric socially efficient outcome. Games characterized by strategic substitutability or strategic complementarity have externalities by nature⁶. In case of a negative externality the Nash equilibrium is Pareto-dominated by lower actions and *vice versa* for games with a positive externality (see Eaton and Eswaran, 2002). In our design we deal with this potential confound by running SUBST and COMPL treatments for both positive and negative externality cases. This gives the following four treatments:

1. strategic substitutes
 - (a) negative externalities (SUBSTneg)
 - (b) positive externalities (SUBSTpos)
2. strategic complements
 - (a) negative externalities (COMPLneg)
 - (b) positive externalities (COMPLpos).

It is straightforward to show that transforming a symmetric game with positive externalities into one with negative externalities can be done without changing incentives. Suppose that the decision variable of player i in a positive externality game is represented by x_i , with $x_i \in [0, m]$. The transformation of this game into one with a negative externality—without changing incentives—is achieved by replacing the decision variable x_i by $m - y_i$ for $i = 1, 2$, where y_i is the decision variable of player i in the corresponding negative externality game. The transformation is related to the transformation of a public good into a public bad game, or of a give-some into a take-some game (see, e.g., Andreoni, 1995; van Dijk and Wilke, 2000).

For the comparison across treatments to be ‘clean’, we require that both theoretical benchmarks—the Nash equilibrium and the joint payoff maximum

⁶This immediately follows from the fact that $\frac{\partial^2 U_i}{\partial x_i \partial x_j} \neq 0$ implies $\frac{\partial U_i}{\partial x_j} \neq 0$.

(JPM)—are the same in the COMPL and SUBST treatments. We want to exclude the possibility that the mere location of these benchmarks within the strategy space could cause any of the treatments to appear more cooperative. For instance, if behavior were random and uniform over the strategy space then all of the treatments should look equally non-cooperative. Also we want the *payoff levels* of the two benchmarks to be the same across the treatments. Moreover, we impose the restriction that the ‘optimal defection payoff’—that is, the best response to fully cooperative play by the other player—is the same across the different treatments. This implies that an analysis on the scope for cooperation in the spirit of Friedman (1971) gives the same outcome in all treatments. A final restriction is that the absolute values of the slopes of the (linear) best response functions are the same in the treatments. This ensures that learning processes such as best-reply dynamics and fictitious play generate the same speed of convergence across SUBST and COMPL. Our requirements for SUBST and COMPL can be summarized as follows.

1. Same Nash equilibrium choice,
2. same Nash equilibrium payoff,
3. same JPM choice (conditional the sign of the externality),
4. same JPM payoff,
5. same optimal defection payoff,
6. same absolute values of the slopes of the best response functions.

Figure 1 visualizes requirements 1, 3 and 6. The Nash equilibrium is in the middle of the strategy space in each of the treatments. The distance to the JPM point is the same in all treatments. The (linear) best response functions are equally ‘steep’ across the treatments.

We use quadratic payoff functions with six parameters for the stage games. This allows us to impose the six requirements listed above. The payoff function of player i in a two-player positive externality COMPL game is defined as follows:

$$\pi_i^{\text{COMPLpos}}(x_i, x_j) = a + bx_i + cx_j - dx_i^2 + ex_j^2 + fx_ix_j, \quad (1)$$

with $b, c, d, f > 0$, $e \geq 0$, $i, j = 1, 2$ and $j \neq i$. It is easy to verify that the game generates a positive externality and is one of strategic complements. The Nash equilibrium is unique and symmetric:

$$x^{\text{Nash}} = \frac{b}{2d - f}, \quad (2)$$

where $2d > f$ for x^{Nash} to be strictly positive. The joint payoff maximizing choice is also unique and symmetric:

$$x^{\text{JPM}} = \frac{b + c}{2(d - e - f)}, \quad (3)$$

where $d > e + f$ for x^{JPM} to be strictly positive.

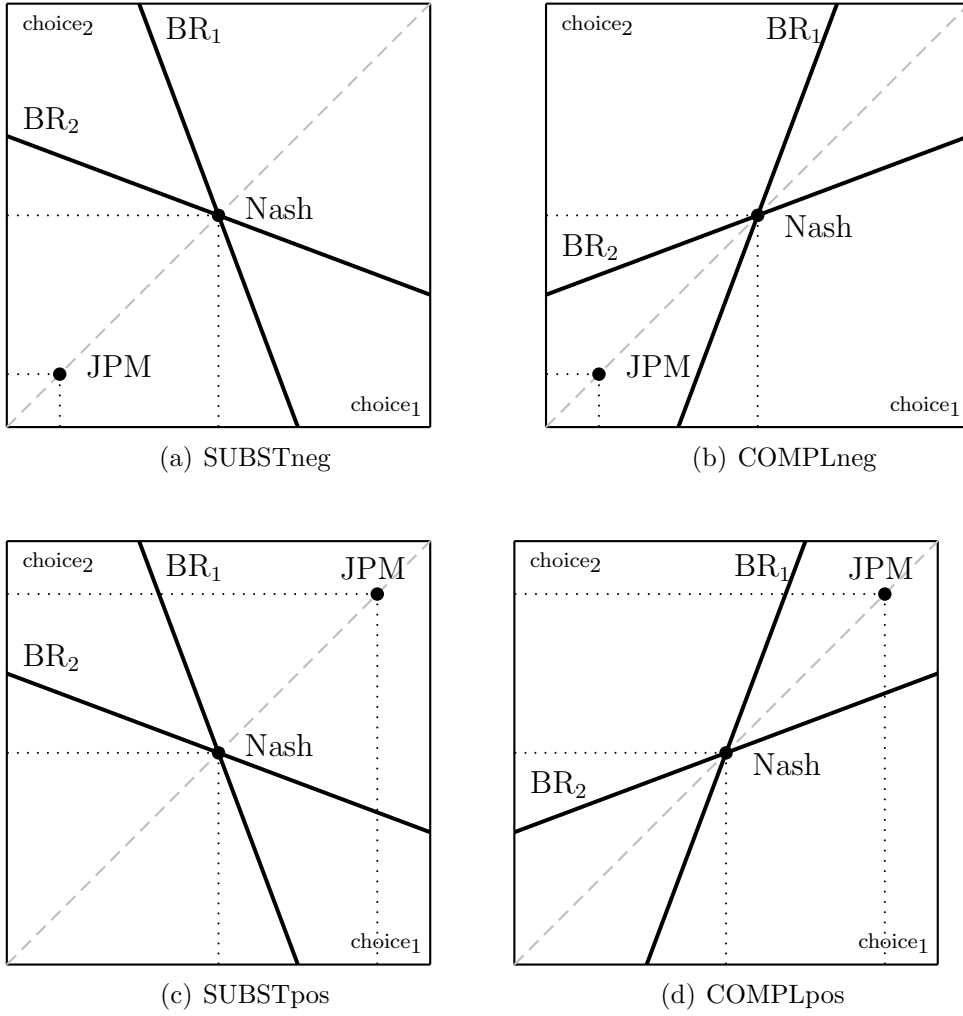


Figure 1: Best-response functions, Nash and JPM choices

In a SUBSTpos game the payoff of player i is defined as follows:

$$\pi_i^{\text{SUBSTpos}}(x_i, x_j) = \alpha + \beta x_i + \gamma x_j - \delta x_i^2 + \epsilon x_j^2 - \zeta x_i x_j, \quad (4)$$

with $\beta, \gamma, \delta, \zeta > 0$, $\epsilon \geq 0$, $i, j = 1, 2$ and $j \neq i$. The game is one of strategic substitutes and for the game to generate a positive externality, the condition $\gamma + 2\epsilon x_j - \zeta x_i > 0$ should be satisfied. The unique and symmetric Nash equilibrium is equal to

$$x^{\text{Nash}} = \frac{\beta}{2\delta + \zeta}, \quad (5)$$

and the symmetric joint payoff maximizing choice is equal to

$$x^{\text{JPM}} = \frac{\beta + \gamma}{2(\delta - \epsilon + \zeta)}, \quad (6)$$

where $\delta > \epsilon - \zeta$ for x^{JPM} to be strictly positive. For the JPM choice to be symmetric, the condition $\delta > \epsilon + \zeta$ should hold.

As we argued before, transforming a positive into a negative externality game is achieved by replacing the choice variable x_i by $m - y_i$. For the Nash equilibria to be the same across positive and negative externality games, the Nash equilibrium is required to be in the middle of the choice set, such that $m = \frac{2b}{2d - f}$, and minimum and maximum actions are the same across all treatments.

The six restrictions are satisfied, if the parameters $\alpha, \beta, \gamma, \delta, \epsilon$ and ζ are defined in terms of a, b, c, d, e and f in the following way⁷:

$$\left\{ \begin{array}{lcl} \alpha & = & a \\ \beta & = & \frac{b(2d - f)}{2d + f} \\ \gamma & = & c + \frac{2bf}{2d + f} \\ \delta & = & \frac{d(2d - f)^2}{(2d + f)^2} \\ \epsilon & = & e + \frac{2f^3}{(2d + f)^2} \\ \zeta & = & \frac{f(2d - f)^2}{(2d + f)^2}. \end{array} \right. \quad (7)$$

The parameters we used for the experiment are $a = 28, b = 5.474, c = 0.01, d = 0.278, e = 0.0055$ and $f = 0.165$ (which gives $m = 28$). Table 1 pro-

⁷It can be shown that the so-called ‘sucker payoff’, i.e., the payoff of cooperating while the other player defects, is smaller in COMPL than in SUBST if these requirements are met. In other words, it is worse to be cheated on in COMPL than in SUBST in terms of payoff loss. From this perspective one might hypothesize there to be *less* cooperation in COMPL than in SUBST (cf. the cooperation index and index of conflict suggested by Rapoport and Chammah, 1965; Axelrod, 1967, respectively).

	SUBST		COMPL	
	SUBSTneg	SUBSTpos	COMPLneg	COMPLpos
choice _{min}	0.0	0.0	0.0	0.0
choice _{max}	28.0	28.0	28.0	28.0
choice ^{Nash}	14.0	14.0	14.0	14.0
choice ^{JPM}	2.5	25.5	2.5	25.5
π^{Nash}	27.71	27.71	27.71	27.71
π^{JPM}	41.94	41.94	41.94	41.94
π^{defect}	60.14	60.14	60.14	60.14
slope	-0.30	-0.30	0.30	0.30

Table 1: Theoretical benchmarks in the experiment

vides an overview of the main theoretical benchmarks in the four treatments for the parameter constellation used in the experiment⁸.

2.2 Procedure

Six computerized sessions have been conducted in CentERlab at Tilburg University in November 2004 covering the four treatments⁹. In each of the first four sessions one of the four treatments has been run, and in the final two sessions mixes of all treatments have been run in order to balance the number of observations across the four treatments. 110 students participated

⁸We tried to maximize the absolute value of the reaction curves' slope so as to sharpen possible contrasts between strategic substitutes and complements. In doing this we are constrained by the requirement that $y^{\text{JPM}} \geq 0$. Assume that c is very small such that it becomes negligible; $c \approx 0$. In that case the expression for $y^{\text{JPM}} \geq 0$ reduces to

$$y^{\text{JPM}} = \frac{b(2d - 4e - 3f)}{2(d - e - f)(2d - f)}, \quad (8)$$

and the condition $y^{\text{JPM}} \geq 0$ reduces to $2d \geq 4e + 3f$ since $d > e + f$ and $2d > f$. If we also assume that $e \approx 0$ the condition $y^{\text{JPM}} \geq 0$ reduces to $2d \geq 3f$, or $\frac{f}{2d} \leq \frac{1}{3}$. In other words, the slope of the best response function cannot exceed $1/3$. If $c > 0$ or $e > 0$ the condition becomes $\frac{f}{2d} < \frac{1}{3}$ and the absolute value of the slope will always be strictly smaller than $1/3$.

⁹We used the experimental software toolkit *z-Tree* to program the experiment (see Fischbacher, 1999).

in the experiment. They were recruited through e-mail lists of students interested in participating in experiments. Each treatment had 28 participants corresponding to 14 independent observations (pairs), except treatment SUB-STneg which had 26 participants or 13 independent observations.

All participants received the same instructions (see appendix A). The treatments only differed with respect to the payoff function. The subjects were informed on how their earnings depended on their own choices and on the choices of one other participant in the session, which remained the same during the entire experiment. They were asked to choose a number between 0.0 and 28.0 in each round¹⁰. Subjects could calculate their earnings in points by means of a payoff table for combinations of hypothetical choices that are multiples of two, and by means of an earnings calculator on the computer screen for any combination of hypothetical choices¹¹. They were explicitly told that choices were not restricted to be multiples of two.

The same static game was repeated 31 times including a trial round which did not count to calculate earnings. Earnings were denoted in points and transferred to cash at a rate of 100 points = 1 EUR. Subjects were informed on the number of rounds. The sessions lasted between 50 and 55 minutes and average earnings were 9.30 EUR.

3 Experimental results

The data are presented in terms of the degree of cooperation which for pair k in round t is defined as:

$$\rho_{kt} = \frac{\text{average choice}_{kt} - \text{choice}^{\text{Nash}}}{\text{choice}^{\text{JPM}} - \text{choice}^{\text{Nash}}}.$$

$\rho_{kt} = 0$ when the average choice of pair k in round t is the non-cooperative Nash equilibrium, while $\rho_{kt} = 1$ when it is the joint payoff maximum. When the average choice of the pair is between the Nash and the JPM benchmark, $0 < \rho_{kt} < 1$. Average choices more competitive than the Nash equilibrium imply that $\rho_{kt} < 0$. This transformation of choices is made in order to simplify comparison across treatments and has no impact on any of our conclusions¹².

¹⁰The number of possible decimal points was limited to one.

¹¹Earnings in points were rounded at two decimals. Pay-off tables are in appendix A. In order to show the difference in the best response functions between strategic substitutes and complements, best responses for multiples of two are marked in grey (which was not the case in the experiment).

¹²Alternatively, the degree of cooperation could have been calculated in terms of the average realized payoffs: (average payoffs - Nash payoffs)/(JPM payoffs - Nash payoffs).

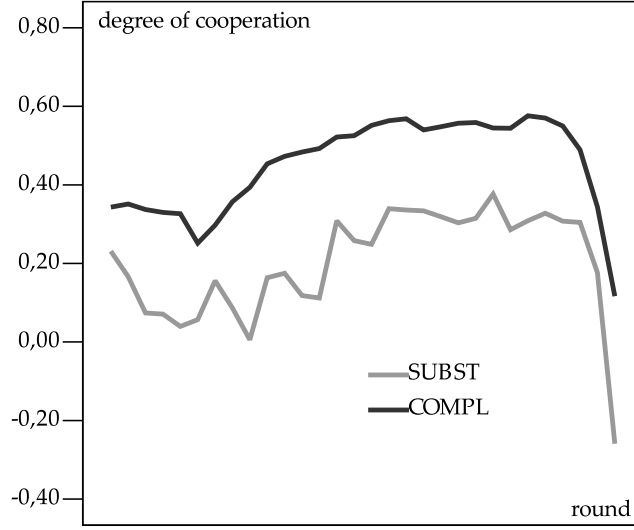


Figure 2: Average degree of cooperation

A first result is that the sign of the externality does not effect the degree of cooperation in SUBST nor in COMPL. Averaged over the pairs and over the rounds, the degree of cooperation is 0.24 in SUBSTneg as compared to 0.17 in SUBSTpos, and it is 0.49 in COMPLneg as compared to 0.42 in COMPLpos. These differences are not statistically significant¹³. Therefore, in what follows we pool SUBSTneg and SUBSTpos into SUBST and COMPLneg and COMPLpos into COMPL.

Our main experimental result is expressed in figure 2, which depicts the evolution of the average degree of cooperation in the SUBST and COMPL treatments. Clearly, the data support the hypothesis that strategic complementarity facilitates cooperation compared to strategic substitutability. Table 2 provides statistical details for all rounds combined (1-30), and separately for the first half (1-15) and the second half (16-30) of the experiment. The second and third column give averages (and standard deviations) of the degree of cooperation for SUBST and COMPL, respectively. The p -values in the 4th column correspond to Mann-Whitney-U test statistics of the null hypothesis that the degree of cooperation is the same in SUBST and COMPL. H_0 is rejected in favor of the alternative hypothesis that the degree of cooperation is larger in COMPL than in SUBST.

Figure 2 further shows that end-effects have occurred in all treatments,

Doing so does not alter any of our conclusions.

¹³Nonparametric test statistics for $H_0 : \bar{\rho}^{\text{neg}} = \bar{\rho}^{\text{pos}}$ are in appendix B.

	$\bar{\rho}$ (s.d.)		p -value ^a
	SUBST	COMPL	
rounds 1-30	0.20 (0.41)	0.45 (0.38)	0.012
rounds 1-15	0.13 (0.38)	0.40 (0.39)	0.006
rounds 16-30	0.27 (0.54)	0.51 (0.40)	0.050
N	27	28	
^a $H_1 : \bar{\rho}_{\text{SUBST}} < \bar{\rho}_{\text{COMPL}}$ (one-tailed)			

Table 2: Treatment effect: SUBST versus COMPL

which is common in finitely repeated social dilemma games (see e.g. Ledyard, 1995; Selten and Stoecker, 1986). This suggests that cooperation during the experiment is at least partly due to strategic considerations. The end-effect is significantly stronger in SUBST than in COMPL, which is not surprising given the difference in the best response function between SUBST and COMPL.

As we outlined in the introduction, the hypothesis for differences in the degree of cooperation is based on the fact that strategic complementarity gives a player an incentive to follow behavioral changes of the other player, while strategic substitutability gives a player an incentive to move in the opposite direction. However, we cannot fully recover these behavioral patterns from the data. In fact, we find that a behavioral change by one player is on average followed by a move in the same direction by the other player in *both* COMPL and SUBST. This implies that if one player moves toward the joint payoff maximum, the average move of the other player in the next round is in the same direction in COMPL as well as in SUBST. However, the extent to which such a move is followed is significantly greater in COMPL than in SUBST on average¹⁴. This pattern can be explained well by the presence of reciprocal players, that is, players who respond cooperatively to cooperative acts and non-cooperatively to non-cooperative acts¹⁵. Since such players follow cooperative choices by others, their presence generates a form of strategic complementarity. This endogenous strategic complementarity is strengthened by the strategic complementarity embedded in the payoff structure of COMPL, while it is—at least partially—compensated by the strategic substitutability inherent in SUBST.

¹⁴For example, a panel regression of Δx_{it} on Δx_{jt-1} with individual AR(1) error processes gives an estimated slope of 0.10 for SUBST and 0.31 for COMPL.

¹⁵There exists ample evidence for the presence of such players. See, for instance, Axelrod and Hamilton (1981), Fischbacher et al. (2002) and Bowles and Gintis (2005).

4 Concluding remarks

We find experimental evidence for the hypothesis that environments with strategic complements lead to more cooperative play than comparable environments with strategic substitutes. At the same time, we find no evidence for an effect of the sign of the externality on the degree of cooperation. Our findings fit together with what Fehr and Tyran (2005) and Camerer and Fehr (2006) propose: under strategic complementarity, and not so under strategic substitutability, a small number of so-called less-rational—for instance, reciprocal and conditionally cooperative—agents may drive the aggregate outcome away from the fully rational equilibrium.

In his survey on industrial organization experiments, Holt notes that it seems easier to collude in Bertrand price-setting games than in Cournot quantity-setting games: “if tacit collusion causes prices to be above non-cooperative levels in price-choice environments, then why do quantities tend to be above noncooperative, Cournot levels (...)?” (Holt, 1995, pages 423–424). Our results suggest that these differences are, at least partly, due to the sign of the best response function’s slope, and not, for example, to the sign of the externality. The same suggestion applies to the higher degree of cooperation that has been found in experimental R&D games with technological spillovers (strategic complements) than in those without spillovers (strategic substitutes) (see Suetens, 2005).

It is not only in industrial organization that the prevalence of voluntary cooperation may interact in an important way with the type of strategic interaction. Consider, for example, a situation where individuals are asked to make contributions to a public good, which is as a matter of fact characterized by positive externalities. Depending on whether the production of the public good has decreasing or increasing returns-to-scale, contributions are strategic substitutes or complements, respectively. Team production, where members of a team decide how much effort to put into a team task, is another example of a situation with positive externalities where actions can be either strategic substitutes or complements. Strategic complementarities are also likely to be present in dilemma environments such as arms races between enemy nations and conspicuous consumption, while common-pool resource dilemmas, strategic trade policy and patent races rather tend to be characterized by strategic substitutability. Due recognition of the underlying type of strategic interaction can help us understand the scope for cooperation in each of these environments.

Appendix A: Instructions

You are participating in an experiment on economic decision-making and will be asked to make a number of decisions. If you follow the instructions carefully, you can earn a considerable amount of money. At the end of the experiment, you will be paid your earnings in private and in cash.

During the experiment you are not allowed to talk to other participants. If something is not clear, please raise your hand and one of us will help you.

Your earnings depend on your own decisions and on the decisions of one other participant. The identity of the other participant will not be revealed. The other participant remains the same during the entire experiment and will be referred to by ‘the other’ in what follows.

The experiment consists of 30 periods. In each period you have to choose a number between 0.0 and 28.0. The other also chooses a number between 0.0 and 28.0. Your earnings in points depend on your choice and the other’s choice. The table attached to these instructions gives information about your earnings for some combinations of your choice and the other’s choice. The other gets the same table.

You can calculate your and the other’s earnings in more detail (for choices that are no multiples of 2 for instance) by using the EARNINGS CALCULATOR on your screen. By filling in a hypothetical value for your own choice and a hypothetical value for the other’s choice you can calculate your and the other’s earnings for this combination of choices.

You enter your decision under DECISION ENTRY by clicking on ‘Enter’.

In each period you have about 1 minute to enter your decision.

After each period you are informed about the other’s choice and your and the other’s earnings in that period. A history of your and the other’s past choices and earnings is available at the bottom right of your computer screen.

The first period is a trial period and does not count when calculating your earnings. Your total earnings in points are the sum of your earnings in points over the 30 periods. Your earnings in points will be converted into EUR according to the following rate: 100 points = 1 EUR.

		The other's choice →														
		0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0
Your choice ↓	0.0	41.27	36.50	31.91	27.50	23.27	19.22	15.36	11.68	8.18	4.87	1.73	-1.22	-3.99	-6.57	-8.98
	2.0	46.88	41.91	37.13	32.52	28.10	23.86	19.81	15.93	12.24	8.73	5.40	2.26	-0.71	-3.49	-6.09
	4.0	51.84	46.68	41.70	36.90	32.28	27.85	23.60	19.53	15.64	11.94	8.42	5.08	1.92	-1.05	-3.85
	6.0	56.14	50.78	45.61	40.62	35.81	31.18	26.74	22.47	18.39	14.49	10.78	7.25	3.89	0.72	-2.26
	8.0	59.79	54.24	48.87	43.68	38.68	33.86	29.22	24.76	20.49	16.40	12.49	8.76	5.21	1.85	-1.33
	10.0	62.78	57.04	51.48	46.10	40.90	35.88	31.05	26.40	21.93	17.64	13.54	9.62	5.88	2.32	-1.06
	12.0	65.12	59.18	53.43	47.85	42.46	37.25	32.22	27.38	22.72	18.24	13.94	9.82	5.89	2.14	-1.43
	14.0	66.81	60.67	54.72	48.96	43.37	37.97	32.75	27.71	22.85	18.17	13.68	9.37	5.24	1.30	-2.46
	16.0	67.84	61.51	55.37	49.41	43.63	38.03	32.61	27.38	22.33	17.46	12.77	8.27	3.95	-0.19	-4.15
	18.0	68.22	61.70	55.36	49.20	43.23	37.43	31.83	26.40	21.15	16.09	11.21	6.51	2.00	-2.34	-6.49
	20.0	67.94	61.23	54.69	48.34	42.17	36.19	30.38	24.76	19.32	14.07	8.99	4.10	-0.61	-5.14	-9.48
	22.0	67.01	60.10	53.37	46.83	40.47	34.29	28.29	22.47	16.84	11.39	6.12	1.03	-3.87	-8.59	-13.13
	24.0	65.43	58.32	51.40	44.66	38.11	31.73	25.54	19.53	13.70	8.06	2.59	-2.69	-7.78	-12.70	-17.43
	26.0	63.19	55.89	48.77	41.84	35.09	28.52	22.14	15.93	9.91	4.07	-1.58	-7.06	-12.35	-17.46	-22.39
	28.0	60.29	52.80	45.49	38.37	31.42	24.66	18.08	11.68	5.47	-0.57	-6.42	-12.09	-17.57	-22.88	-28.00

Figure 3: Pay-off table for SUBSTneg

		The other's choice →														
		0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0
Your choice ↓	0.0	-28.00	-22.88	-17.57	-12.09	-6.42	-0.57	5.47	11.68	18.08	24.66	31.42	38.37	45.49	52.80	60.29
	2.0	-22.39	-17.46	-12.35	-7.06	-1.58	4.07	9.91	15.93	22.14	28.52	35.09	41.84	48.77	55.89	63.19
	4.0	-17.43	-12.70	-7.78	-2.69	2.59	8.06	13.70	19.53	25.54	31.73	38.11	44.66	51.40	58.32	65.43
	6.0	-13.13	-8.59	-3.87	1.03	6.12	11.39	16.84	22.47	28.29	34.29	40.47	46.83	53.37	60.10	67.01
	8.0	-9.48	-5.14	-0.61	4.10	8.99	14.07	19.32	24.76	30.38	36.19	42.17	48.34	54.69	61.23	67.94
	10.0	-6.49	-2.34	2.00	6.51	11.21	16.09	21.15	26.40	31.83	37.43	43.23	49.20	55.36	61.70	68.22
	12.0	-4.15	-0.19	3.95	8.27	12.77	17.46	22.33	27.38	32.61	38.03	43.63	49.41	55.37	61.51	67.84
	14.0	-2.46	1.30	5.24	9.37	13.68	18.17	22.85	27.71	32.75	37.97	43.37	48.96	54.72	60.67	66.81
	16.0	-1.43	2.14	5.89	9.82	13.94	18.24	22.72	27.38	32.22	37.25	42.46	47.85	53.43	59.18	65.12
	18.0	-1.06	2.32	5.88	9.62	13.54	17.64	21.93	26.40	31.05	35.88	40.90	46.10	51.48	57.04	62.78
	20.0	-1.33	1.85	5.21	8.76	12.49	16.40	20.49	24.76	29.22	33.86	38.68	43.68	48.87	54.24	59.79
	22.0	-2.26	0.72	3.89	7.25	10.78	14.49	18.39	22.47	26.74	31.18	35.81	40.62	45.61	50.78	56.14
	24.0	-3.85	-1.05	1.92	5.08	8.42	11.94	15.64	19.53	23.60	27.85	32.28	36.90	41.70	46.68	51.84
	26.0	-6.09	-3.49	-0.71	2.26	5.40	8.73	12.24	15.93	19.81	23.86	28.10	32.52	37.13	41.91	46.88
	28.0	-8.98	-6.57	-3.99	-1.22	1.73	4.87	8.18	11.68	15.36	19.22	23.27	27.50	31.91	36.50	41.27

Figure 4: Pay-off table for SUBSTpos

		The other's choice →														
		0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0
Your choice ↓	0.0	41.27	31.42	21.61	11.84	2.12	-7.56	-17.19	-26.78	-36.33	-45.83	-55.29	-64.70	-74.07	-83.40	-92.68
	2.0	51.11	41.91	32.76	23.66	14.60	5.58	-3.40	-12.33	-21.21	-30.05	-38.85	-47.61	-56.32	-64.98	-73.60
	4.0	58.72	50.19	41.70	33.25	24.85	16.49	8.18	-0.09	-8.32	-16.50	-24.64	-32.73	-40.78	-48.79	-56.75
	6.0	64.11	56.23	48.40	40.62	32.88	25.18	17.52	9.91	2.35	-5.17	-12.65	-20.09	-27.48	-34.82	-42.12
	8.0	67.27	60.06	52.89	45.76	38.68	31.64	24.65	17.70	10.79	3.93	-2.89	-9.66	-16.39	-23.08	-29.72
	10.0	68.21	61.66	55.15	48.68	42.26	35.88	29.55	23.26	17.01	10.81	4.65	-1.46	-7.53	-13.56	-19.54
	12.0	66.93	61.03	55.18	49.38	43.62	37.90	32.22	26.59	21.01	15.47	9.97	4.51	-0.90	-6.26	-11.58
	14.0	63.42	58.19	53.00	47.85	42.75	37.69	32.68	27.71	22.78	17.90	13.06	8.27	3.52	-1.19	-5.85
	16.0	57.69	53.11	48.58	44.10	39.66	35.26	30.90	26.59	22.33	18.11	13.93	9.79	5.70	1.66	-2.34
	18.0	49.73	45.82	41.95	38.12	34.34	30.60	26.91	23.26	19.65	16.09	12.57	9.10	5.67	2.28	-1.06
	20.0	39.55	36.30	33.09	29.92	26.80	23.72	20.69	17.70	14.75	11.85	8.99	6.18	3.41	0.68	-2.00
	22.0	27.15	24.55	22.00	19.50	17.04	14.62	12.24	9.91	7.63	5.39	3.19	1.03	-1.08	-3.14	-5.16
	24.0	12.52	10.59	8.70	6.85	5.05	3.29	1.58	-0.09	-1.72	-3.30	-4.84	-6.33	-7.78	-9.19	-10.55
	26.0	-4.33	-5.61	-6.84	-8.02	-9.16	-10.26	-11.32	-12.33	-13.29	-14.21	-15.09	-15.93	-16.72	-17.46	-18.16
	28.0	-23.41	-24.02	-24.59	-25.12	-25.60	-26.04	-26.43	-26.78	-27.09	-27.35	-27.57	-27.74	-27.87	-27.96	-28.00

Figure 5: Pay-off table for COMPLneg

		The other's choice →														
		0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0
Your choice ↓	0.0	-28.00	-27.96	-27.87	-27.74	-27.57	-27.35	-27.09	-26.78	-26.43	-26.04	-25.60	-25.12	-24.59	-24.02	-23.41
	2.0	-18.16	-17.46	-16.72	-15.93	-15.09	-14.21	-13.29	-12.33	-11.32	-10.26	-9.16	-8.02	-6.84	-5.61	-4.33
	4.0	-10.55	-9.19	-7.78	-6.33	-4.84	-3.30	-1.72	-0.09	1.58	3.29	5.05	6.85	8.70	10.59	12.52
	6.0	-5.16	-3.14	-1.08	1.03	3.19	5.39	7.63	9.91	12.24	14.62	17.04	19.50	22.00	24.55	27.15
	8.0	-2.00	0.68	3.41	6.18	8.99	11.85	14.75	17.70	20.69	23.72	26.80	29.92	33.09	36.30	39.55
	10.0	-1.06	2.28	5.67	9.10	12.57	16.09	19.65	23.26	26.91	30.60	34.34	38.12	41.95	45.82	49.73
	12.0	-2.34	1.66	5.70	9.79	13.93	18.11	22.33	26.59	30.90	35.26	39.66	44.10	48.58	53.11	57.69
	14.0	-5.85	-1.19	3.52	8.27	13.06	17.90	22.78	27.71	32.68	37.69	42.75	47.85	53.00	58.19	63.42
	16.0	-11.58	-6.26	-0.90	4.51	9.97	15.47	21.01	26.59	32.22	37.90	43.62	49.38	55.18	61.03	66.93
	18.0	-19.54	-13.56	-7.53	-1.46	4.65	10.81	17.01	23.26	29.55	35.88	42.26	48.68	55.15	61.66	68.21
	20.0	-29.72	-23.08	-16.39	-9.66	-2.89	3.93	10.79	17.70	24.65	31.64	38.68	45.76	52.89	60.06	67.27
	22.0	-42.12	-34.82	-27.48	-20.09	-12.65	-5.17	2.35	9.91	17.52	25.18	32.88	40.62	48.40	56.23	64.11
	24.0	-56.75	-48.79	-40.78	-32.73	-24.64	-16.50	-8.32	-0.09	8.18	16.49	24.85	33.25	41.70	50.19	58.72
	26.0	-73.60	-64.98	-56.32	-47.61	-38.85	-30.05	-21.21	-12.33	-3.40	5.58	14.60	23.66	32.76	41.91	51.11
	28.0	-92.68	-83.40	-74.07	-64.70	-55.29	-45.83	-36.33	-26.78	-17.19	-7.56	2.12	11.84	21.61	31.42	41.27

Figure 6: Pay-off table for COMPLpos

Appendix B: Externality treatment effects

	$\bar{\rho}_{\text{SUBST}}$ (s.d.)			$\bar{\rho}_{\text{COMPL}}$ (s.d.)		
	neg	pos	p -value	neg	pos	p -value
rounds 1-30	0.24 (0.42)	0.17 (0.41)	0.519 ^a	0.49 (0.42)	0.42 (0.36)	0.795 ^a
rounds 1-15	0.22 (0.39)	0.06 (0.37)	0.128 ^a	0.45 (0.43)	0.34 (0.35)	0.511 ^a
rounds 16-30	0.26 (0.53)	0.28 (0.56)	0.730 ^b	0.53 (0.43)	0.49 (0.39)	0.982 ^b
N	13	14		13	14	
^a $H_1 : \bar{\rho}_{\text{neg}} > \bar{\rho}_{\text{pos}}$; ^b $H_1 : \bar{\rho}_{\text{neg}} < \bar{\rho}_{\text{pos}}$ (two-tailed)						

Table 3: Externality treatment effects

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